Transport Beam Instrumentation: A First Look

J. Douglas Gilpatrick
Beam Transport Team and
LANSCE-1 Beam Diagnostic Instrumentation Team

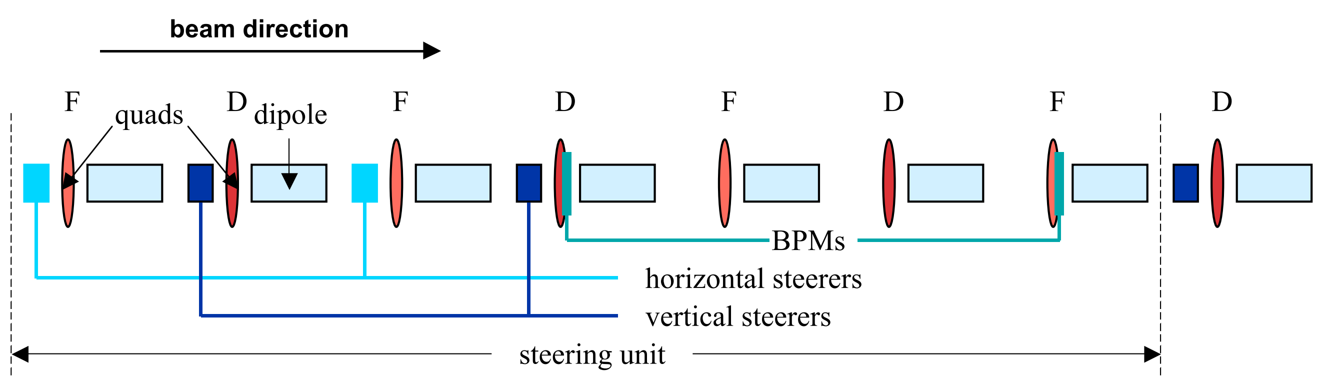
Los Alamos

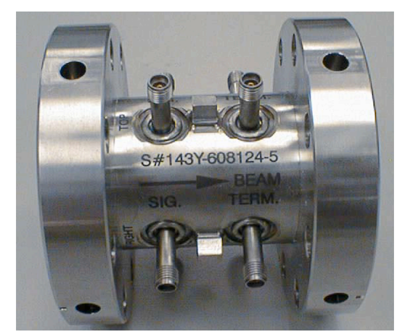
Agenda

- Define the primary measurements in the transport
  - Position
  - Transverse profiles
  - Charge and Current
  - Loss
  - Specialty measurements for tuning
- Discuss a suggested placement guidance for each measurement
- Discuss choices we are investigating for each measurement
- Suggest an initial set of specifications, as guided by the transport physics
- Provide a first cut at the numbers of each measurement
- List TBD items

Transport Beam Position Measurements: Design Philosophy

- **Placement Guidance**
  - Periodic lattice (dual-axis beam position monitor)
    - Pair per 3.5 FODO lattice periods (see below)
  - Downstream from beam splitter for assessment of centering split beams
- **Beam Position Monitors (BPMs) under investigation**
  - Resistive wall current monitor
    - Advantages: non-differentiating, no RF vacuum feedthroughs
    - Disadvantages: physically larger, requires ferrite
  - Micro-stripline Sensor/Button (Capacitive) sensor
    - Difficult to practically manufacture electrode longer than 20-ns bunch length
    - Advantages: physically short, no ferrite
    - Disadvantages: Doublet signal w/ small S:N, multiple RF vacuum feedthroughs



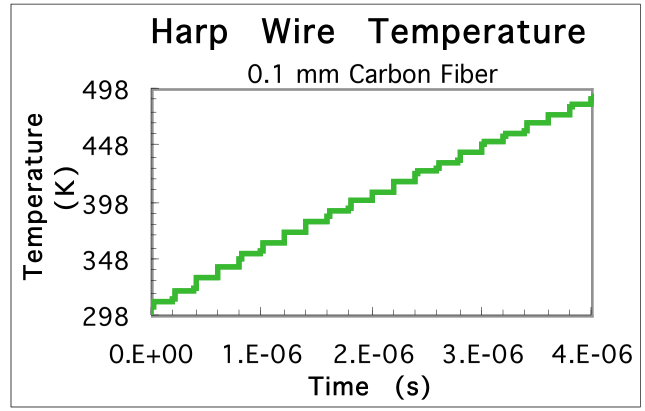


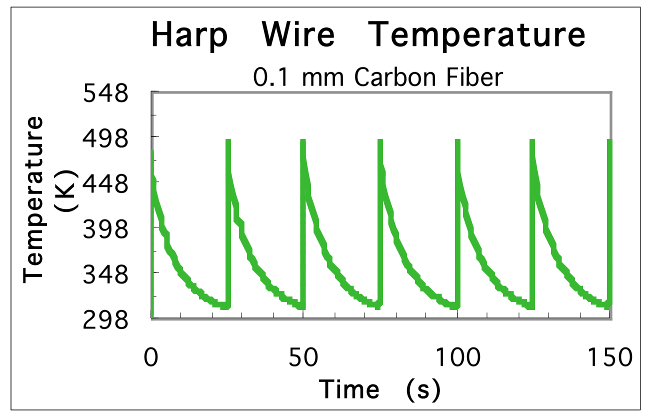
Initial Beam Position Specifications as Guided by Transport Physics

- **Precision: ~0.1% of half aperture**
- **Accuracy: ~1% of half aperture**
  - Apertures (Beam Pipe ID): 2 in, 3 in, and 4 in
- **Rise Time: ~20 ns (implies 18 MHz BW)**
  - For most measurements: average beam position for a single pulse
- **Dynamic Range: $1.5X10^{12}$ to $5X10^{8}$ protons per bunch**
  - Single synchrotron bunch partially filled from the linac/booster
  - 3 Splits likely extends dynamic range to $1.5X10^{12}$ to $1X10^{8}$
- **Position Acquisition Time: ≤ 50 ns**
- **Nominal synchrotron output: 1-20 bunches each separated by 200 ns**
- **Time difference between 20-bunch "shot" and positions posted to archiver and operator screens: < 1 s**

Beam Profile Measurements: Design Philosophy

- **Placement Guidance**
  - **Periodic lattice after each splitter**
    - **Sufficient profile measurements to characterize the beam match to the next optics section**
    - **1 per each FODO lattice section for troubleshooting issues**
  - **Beam splitters**
    - **Before PM Septum, DC Septum #1 and DC Septum #2**
- **Possible profile measurement choices under investigation**
  - **Harps (multi-wires, secondary electrons)**
    - **Advantages: radiation tolerant, robust, detection conceptually simpler**
    - **Disadvantages: provides only projections, can have coupling between wires, spatial resolution limitations (0.25-mm minimum wire spacing)**
  - **Viewscreens w/ video imaging systems (Detected light: several choices)**
    - **Advantages: directly measures full 2-D information of the beam**
    - **Disadvantages: detectors more radiation sensitive (rad. hard cameras?), beam heating issues**





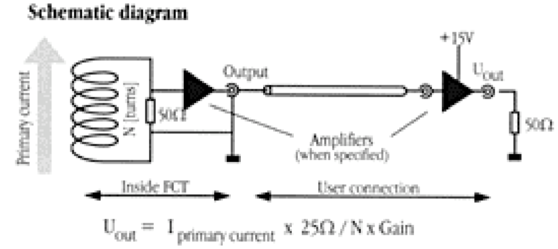
Initial Beam Profile Specifications as Guided by Transport Philosophy

- **Spatial and Charge Precision: ~20% rms width and ~2% of full scale charge**
- **Spatial and Charge Accuracy: ~50% rms width and 50% of FS Charge (relative information more important)**
- **Rise Time: ~20 ns (implies 18 MHz BW)**
  - **Need only to collect profile integrated over a single pulse**
- **Dynamic Range: ~ ±3 rms widths**
- **Measurement Region: ±75% of beam pipe half aperture**
- **Profile Thresholds: ~ 1% of the distribution peak**
- **Overall repetition rate: 0.04 Hz (a group of 20 bunches every 25 s)**
- **Profile Acquisition Time: typically < 1 s (in some cases ≤ 50 ns)**
  - **Most profile measurements need only provide a single distribution for a group of 20 bunches**
  - **A few profile measurements in transport will need to detect individual bunch profiles**

Beam Charge and Current Measurements: Design Philosophy

- **Placement Guidance**
  - Periodic lattice: bends and straight sections
    - 1 per each FODO lattice section for commissioning and operation
  - Beam splitters (~5)
    - 1 in front of splitter, 1per splitter leg after DC magnetic septum #2 and 1 per splitter leg at end
- **Current and Charge measurement choices**
  - Fast current/charge transformers that integrate the bunch charge (Typical Bergoz FCT)
    - Advantages: non-interceptive, off-the-shelf product, reasonably low cost, sensitive, radiation tolerant and robust
    - Disadvantages: none for this application
  - Additionally, BPM can provide a similar charge/current measurement
    - Advantages: non-interceptive, reasonably low cost, sensitive, very radiation tolerant and robust
    - Disadvantages: none for this application

Schematic diagram



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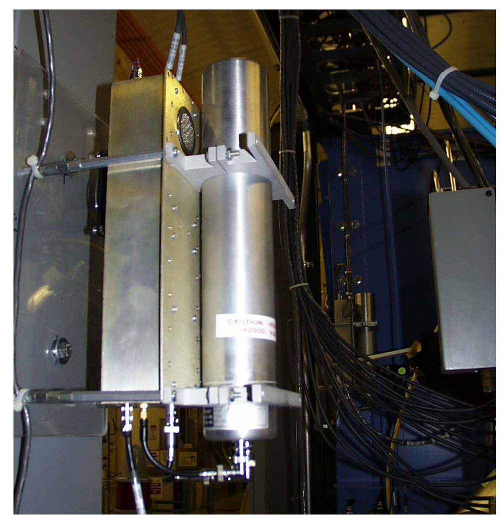
Initial Beam Charge and Current Specifications as Guided By Transport Physics

- Precision: ~0.25% of full scale current
- Accuracy: ~0.5% of full scale current
- Rise Time: ~ 1 ns (implies 350 MHz BW)
  - Some locations: differentiate signal for individual bunch shapes
  - For most locations: average beam charge/current for a single pulse sufficient
- Dynamic Range: 1.5×10^{12} to 5×10^{8} Protons per bunch
  - Single synchrotron bunch partially filled from the linac/booster
- Current Acquisition Time: $\leq$ 50 ns
  - Nominal synchrotron output: 1- 20 bunches each separated by 200 ns
- Time difference between 20-bunch "group" and currents posted to archiver and operator screens: < 1 s

Beam Loss Measurements: Design Philosophy

- Placement Guidance (tuning and troubleshooting during operation)
  - Periodic lattice in each bend
    - One per 2 dipoles (beam is bent 7.5 deg per 20 m long cell)
  - Periodic lattice in each straight section
    - One per 2 FODO lattice periods
  - Beam splitters (~ 10)
    - One at Electrostatic Splitter, Pulsed Magnet Septum, DC Magnet Septum #1 and DC Magnet Septum #2, and
    - One near each scraper
- Loss measurement under investigation
  - Ion Chambers
    - Advantages: wide dynamic range, does not saturate, robust
    - Disadvantages: not as sensitive as other choices, relatively slow
  - Diodes w/ counting type detectors
    - Advantages: sensitive, fast, low cost
    - Disadvantages: can saturate
  - Others? (Scintillator + PMT, cable-based loss detector, or other solid state detector)



Initial Beam Loss Specifications as Guided by Transport Physics

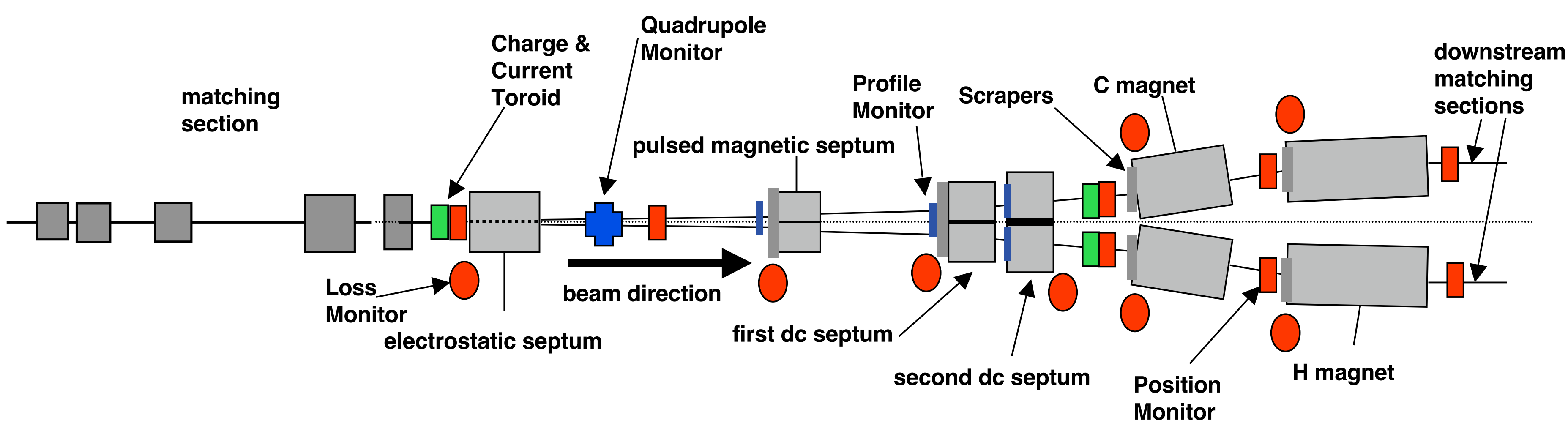
- Precision: ~10^7 lost protons
- Accuracy: within X10 of actual loss (relative information more important)
- Rise Time: ~20 ns (implies 18 MHz BW)
  - Locate beam loss to somewhere between adjacent loss monitors
- Dynamic Range: 1×10^{11} to 1×10^7 Protons per bunch
  - Single synchrotron bunch partially filled from the linac/booster
- Loss Acquisition Time: ≤ 50 ns
  - Nominal synchrotron output: 1-20 bunches each separated by 200 ns
- Time difference between 20-bunch “shot” and losses posted to archiver and operator screens: < 1 s

Measurements for Special Beam-Related Tuning Parameters

- **Septum beam current**
  - Measurement of approximate centering of split beam
  - Wires on both sides of septum provide information of where the bulk of the distribution reaches the septum
  - Detect secondary emission resulting from 50 GeV protons intercepting the biased wire
- **Scraper beam current**
  - Measurement of number of protons intercepting scrapers in front of septum
  - Detect secondary emission resulting from 50 GeV protons intercepting the biased scraper
- **Quadrupole Moment**
  - Non-interceptive monitor provides additional split-beam separation information between the pulsed magnet and DC magnet splitters.

Beam instrumentation in the splitter region provide operators with beam tuning information.

- Splitter region must have sufficient beam instruments to
  - Split beam pulses in half to within <1%
  - Position beam for next periodic lattice
  - Match beam for next periodic lattice
  - Scrape off halo from distribution edges of split beams
  - Monitor placement and amount of separation of split beams



Number of Measurement and General Location in the Transport: Initial Estimate

	Current & Charge	Loss	Septum Current	Scrapper Current	Position	Trans. Profile	Quad Moment
Splitter #1 (Matching & 6 single axis steerers)	5	10	3	16	8	4	1
Bend #1 (2; 18 dipoles &quads, 8 steerers)	2	18	0	0	8	8	0
Straight Section #1 (2; 39 quads & 20 steerers)	2	20	0	0	20	2	0
Bend #2 (2; 30 dipoles &quads, 16 steerers)	0	30	0	0	16	2	0
Splitter #2 (2, Matching & 6 single axis steerers)	10	20	6	32	16	8	2
Bend #3 (4; 12 dipoles &quads, 4 steerers)	0	24	0	0	8	16	0
Straight Section #2 1 (4; 7 quads & 4 steerers)	4	8	0	0	8	4	0
Bend #4 (4; 18 dipoles &quads, 8 steerers)	0	36	0	0	16	4	0
Splitters #3 (4, 2 Matching & 12 single axis steerers)	36	80	24	128	60	32	8
Bend #5 (8; 4 dipoles &quads, 2 steerers)	0	16	0	0	0	32	0
Straight Section #3 (8; 4 quads & 2 steerers)	8	8	0	0	16	0	0
Outer Bend Section #4 (8, 8 dipoles, 8 quads, 2 steerer)	8	32	0	0	16	8	0
Middle Straight Section #4 (4, 1 triplett, 2 dipoles, 2 H/V steerers)	4	8	0	0	8	4	0
Total	79	310	33	176	200	124	11

Transport Beam Measurement TBDs

- Commissioning plan and how the instrumentation answer it's related requirements
- Complete measurement choice selection
- Integrated control system interface (hardware and software)
- Timing system interface
- Mechanical beamline interfaces (flanges, support structures, etc.)
- Vacuum constraints/requirements
- Facility/building interface issues (cable trays/conduits, environment, etc.)
- Beamline device alignment
- Grounding of beamline devices and electronics
- Cable plant
- Others?

Summary

- We have a start on the baseline for the AHF transport beam instrumentation and we are refining it.
  - We have identified what beam parameters are important to measure
  - Their general location
  - And their approximate numbers
- We have a starting set of requirements for each measurement.